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ABSTRACT

This paper discusses the effects of the instructional use of computers and projects possibilities for their home use. Following a brief introduction, exemplar studies of two computer assisted instruction programs--TICCIT and PLATO--are described. The TICCIT study contrasted the performance of over 5,000 community college students in classes taught primarily by computer with the performance of similar students from lecture/discussion sections of the same courses. The PLATO evaluation included both a large scale demonstration with approximately 4,000 students in community colleges and a smaller demonstration with 1,000 students in elementary classrooms. Research methodologies and findings are given for each study. A 4-year longitudinal study of the uses of CAI for compensatory education in the elementary grades that was conducted in Los Angeles is also described. Several literature reviews and meta analyses are then presented which examine the educational uses of computers and learner control in computer-based education. Comparisons are drawn between the instructional effectiveness of computers and educational television, and supportive findings are presented from evaluations conducted during the early years of "Sesame Street" and "The Electric Company" to determine their educational value. Studies which examine computer equity issues are also reviewed. A brief discussion of new challenges and problems for the educational establishment that will result from computer-based instruction in the home concludes the paper. (JB)

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FINAL DRAFT

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Is Computer-based Instruction Ready to Move into the Home?

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Introduction

The literature on the effects of the instructional use of computers is voluminous. In 1972, Vinsonhaler & Bass reviewed the results of ten major studies of computer-assisted instruction. In 1974, as part of a major overview of the effects of several different kinds of technology on achievement and other outcomes, Jamison, Suppes, and Wells reviewed 19 studies related to computers. By 1980, Kulik and his associates identified more than 500 studies related to computer-based instruction at the college level alone.

The literature is also varied. Studies range in their approach from anecdotal or observational accounts of classroom computer activities to carefully designed quasi-experiments, with appropriate comparison groups. The studies vary according to the subject matter covered, the grade levels, and the length of exposure to the computer, both in terms of hours per day or per week and length of the experimental treatment. Longitudinal studies are rare. Outcomes measured vary as well. Most studies are concerned with achievement in one form or another. Many are also concerned with course or unit completion rates and with the time it takes students to complete courses or units. Attitudes are often measured as well. Most commonly, attitudes toward the particular subject matter of interest, toward instruction in general, and toward the computer are assessed. Some studies examine costs and cost-benefits. Studies vary in the specific measures they employ to measure the outcomes they examine. Finally, analytical approaches vary.

Studies may also vary according to whether the computer is used to supplement or supplant traditional classroom instruction. The treatments assessed include drill-and-practice, tutorial lessons, simulations, and games. Other variations may include the instructional organization (is the computer in the classroom or in a separate facility like a lab or center?), whether the same teacher is involved in both the computer-related instruction and the non-computer parts of the course, and whether the same teacher teaches both the experimental and the comparison or control group in the study.

The typical study, if it is appropriate to characterize any study in such fashion, takes place in an existing educational institution, and focuses on one or a limited number of subject areas, in one or a limited range of grade levels. Some attempt may be made at random assignment of students to computer and comparison classroom groups. All students are exposed to instruction over some pre-established time period, after which outcome measures are collected.

Since all of these studies cannot be reviewed here, two are reported briefly as exemplars. Following the account of the two studies, several comprehensive reviews and meta-analyses will be described.

Both of the exemplar studies are unusual in their scope, one because of the number and range of variations it encompasses and the other because it includes a longitudinal study. Both were well-planned and well-executed, within the constraints of the on-going life of educational institutions. Both, as it happens, were conducted by researchers at Educational Testing Service.

The TICCIT and PLATO Evaluations

TICCIT - the program. The TICCIT program (Time-shared, Interactive, Computer-Controlled Information Television) developed by the MITRE Corporation, with support from the National Science Foundation, is a small computer system designed to support instruction within a school. The ETS evaluation of TICCIT was intended as a major demonstration of the effectiveness of computer-assisted instruction. For purposes of this demonstration project, community colleges were chosen as the target population and English and mathematics were chosen as the subject areas of interest. The choice of these subjects was predicated on their affecting the largest possible number of students within any given community college. The evaluation report (Alderman, 1978) documents the results of the use of the TICCIT program at two community colleges, and contrasts the performance of students in classes taught primarily by computer with the performance of similar students from lecture/discussion sections of the same courses. The outcomes examined were rates of course completion, student achievement in the subject areas, student attitudes, and selected student activities. The evaluation did not examine the cost-effectiveness of the program. It did, however, attempt to measure faculty acceptance of the program and to assess the role of teachers in the courses where instruction was primarily computer-based. The participation of instructors in these courses varied along subject matter lines and within the English courses. In English courses instructors typically chose lessons appropriate for their classes and participated actively in assigning and correcting student work. In mathematics courses instructors tended to manage the courses, which in some cases were three times as large as normal lecture courses, and advise students on their course progress.

All TICCIT courseware conformed to a single instructional design. The content matter was organized hierarchically into three levels, each representing finer detail. Learner control was possible at the segment, or finest detailed, level. Each segment contained a rule with examples, and problems illustrating the application of the rule (a rule-example-practice paradigm). A student could exercise control over the sequence, difficulty level, and frequency of rule and example displays.

Evaluation of the TICCIT program involved over 5,000 students in nearly 200 sections of the target courses. Outcome measures were collected after at least one academic term of exposure to a particular course on the TICCIT system.

Findings. Rate of course completion was defined as the proportion of students who enrolled for and then fulfilled the requirements of the course and received credit for it. The impact of the TICCIT program on course completion was negative in all but one case. The average completion rate for mathematics courses was 16 percent; that is, 16 of every 100 students who enrolled in the course ultimately received credit for it. The comparable rate for traditional lecture/discussion sections of the same course was 50 percent. English courses revealed completion rates of 55 percent for TICCIT classes compared with 66 percent for traditional lecture sections. The author of the report attributes this

negative effect of the TICCIT program to the shift in emphasis from the computer to the student. Through learner control, students had to assume responsibility for their own learning. The author concludes that, "Programs that allow each student to proceed at his or her own pace risk losing students unable to manage their own instruction." This finding was consistent with results from studies of other instructional paradigms that placed increased responsibility on students for the control of learning.

Significant positive achievement effects were observed for both mathematics and English classes, and were significant in five of six cases. Estimates of the effect size indicated about 10 percent improvement over conventional lecture sections for mathematics courses, and about five percent for English courses. The sizes of the effects tended to vary with the particular circumstances of the students and the courses and applied only to the sometimes small proportion of students who completed the courses. Students who tended to profit relatively more than most from the TICCIT courses were students with prior familiarity with the content of the courses, and those with stronger ability entering the course.

Affective reactions to the TICCIT program were related to the manner of its use. Students in mathematics courses overall reacted less favorably to TICCIT classes than did students of comparable ability to their lecture sections. Negative attitudes were also observed among students who took part in English courses in which the instructor determined the extent of student exposure to TICCIT. In the English course in which the instructors' role took the form of explaining the subject matter, reviewing written work, and conducting small group discussions, attitudes were significantly higher at the end of the course than in comparable non-TICCIT courses.

The student activities assessed reflected three central issues. The first was the hope that the TICCIT program would foster positive student reactions to the subject matter. This issue was addressed through questions about students' selection of additional courses in the subject or plans to enter a job related to the field. A second issue reflected the popular conception of instructional technology as impersonal. This was addressed by students' estimates of the frequency of their course-related interpersonal contacts. The final issue reflected the assumption that time devoted to learning is a critical variable in the outcome. Activities measured were how students allocated their learning time, and the relationship between time and learning for students on the TICCIT system. The results related to the activity outcomes were complex and difficult to summarize. "What differences occurred in student self-reports about their activities seemed a natural consequence of the instructional conditions for a course," the author observed. With respect to plans for future courses or jobs, exposure to a course in the field, whether through the TICCIT system or a traditional course, encouraged both. An unexpected finding about the purported impersonality of computer instruction was that students in the TICCIT classes reported as much interpersonal contact as did students in lecture sections.

The box score for the TICCIT evaluation would probably read: win some, lose some, have some rained out. Specifically, course completion rates were higher for traditional instruction, achievement gains were higher for TICCIT instruction, attitudes changed for the better and worse depending on the context of the course, and student activity data indicated a draw for TICCIT and traditional instruction. The importance of the TICCIT evaluation is that it represented a carefully constructed assessment of the multiple effects of a large-scale demonstration of the use of computers for instruction. What seems most notable about the results is the necessity of reading them carefully. The computer appears to have different effects depending on the course context, the role of the instructor, and the students involved. As the author is careful to point out throughout, it is a mistake to assume that the computer is uniformly beneficial or detrimental to all students. The TICCIT study chronicles the progress and outcome of a large-scale demonstration of the instructional uses of computers in a particular institutional setting, and indicates that there are both benefits and limitations to such a system.

PLATO: The community college study. The PLATO evaluation provides an interesting contrast to TICCIT. The PLATO (Programmed Logic for Automatic Teaching Operations) system was developed at CERL, the Computer-based Education Research Laboratory at the University of Illinois with support from the National Science Foundation. In its broadest sense, the system was designed to support 1,000 terminals in a variety of settings from elementary schools through institutions of post secondary education. In practice, the system was not able to support more than several hundred terminals without experiencing a serious degradation in response time. The ETS evaluations included, first, a large-scale demonstration in community colleges and, second, a smaller demonstration in elementary classrooms in the Champaign-Urbana area. In the community college study, five subject areas were included: accounting, biology, chemistry, English, and mathematics. Approximately 4,000 students in 100 different classes in five community colleges used the system during the two years covered by the evaluation. Although instructors, who volunteered to take part in the demonstration, were expected to use PLATO for about one-third of their instructional time, the actual usage varied widely. Class sizes varied as did exposure time per student, the latter ranging from an average of approximately two hours per student per semester to a high of approximately 13 in biology classes alone. The range for all courses was from under an hour to more than 20. Because a major goal of PLATO is to provide individualized instruction, and because instructors were free to use the system as little or as much as they liked, such variation was expected. Thus, there were variations of college setting, course, instructor, materials within course, and exposure. In no way could the PLATO "treatment" be considered as exposure to a standard curriculum or defined in any precise way. The philosophy of the developers was that instruction should be managed by the instructor and individualized at the student level. While PLATO was used mainly during class time, students could also use the system outside of class time. In practice, some did and some didn't, another source of variation. Finally, PLATO lessons were used in some instances to supplant regular

classroom instruction and in other cases to supplement or reinforce it. Across these wide variations in computer-based instruction, outcome measures were taken in three major areas: course completion, student achievement, and student attitudes.

Course completion data were analyzed separately by course within college for each college (n=32). Five of these analyses yielded significant differences between PLATO and control classes in completion. Four were in the positive direction, one in the negative direction. These were explained in terms of instructor differences of chance effects, so that it was concluded that PLATO, unlike TICCIT, had no consistent effect on attrition.

Achievement was assessed using tests constructed for the PLATO study. Pretests were assembled by ETS staff from existing tests, with the participation of course instructors. Posttests were designed in accordance with the curriculum outlines for the various subjects in each college, again with the participation of instructors. In many cases the posttest became the final exam for the course. Again, 32 populations were used in a set of nonequivalent control group designs. Although some effort was made to have instructors teach both PLATO and non-PLATO sections of the same course, control of instructor effects was only partial. It was, therefore, frequently very difficult to partial out the effects due to instructors and the effects due to treatments. Overall, the analyses of posttest scores regressed on pretest scores and other independent variables for the 32 populations indicated neither positive or negative effects of PLATO on achievement. Roughly half of the estimated effects were positive and half negative, and only five (four positive and one negative) were statistically significant. The five significant effects appeared in one mathematics course, one chemistry course, and three different biology courses. Only one effect was thought to represent a real difference due to PLATO, however, since the other four were confounded with instructor variables.

Attitudes of instructors and students in both PLATO and non-PLATO classes were measured before the start and at the end of each section of each course. The questions were many and varied. Overall, analysis of the attitude items revealed a favorable impact of the PLATO demonstration on the attitudes of both participating students and instructors. Those who used the system indicated interest in continuing to do so. Various components of the system were assessed favorably. A small number of weaknesses were identified but, by and large, the strengths appeared to have outweighed the weaknesses.

PLATO: The elementary school study. As part of the demonstration project, 100 terminals were also placed in elementary school classrooms in the Champaign/Urbana area. Lessons intended to supplement, not supplant, regular classroom instruction were developed for beginning reading in grades kindergarten through two and in mathematics in grades four to six. During the demonstration year, about 300 students received mathematics lessons and about 700 students received reading lessons through PLATO. The evaluation of this experience took the form of a naturalistic study

rather than an experiment because teachers had been permitted to choose whether or not to introduce PLATO lessons into their classrooms. Random assignment was, therefore, not possible. Delays and changes characterized the effort from the start (a not atypical experience with the introduction of curriculum innovations in general and technological ones in particular); hardware problems, difficulties with level and routine in the lessons; and the inexperience of teachers with the system required the periodic presence of the courseware developers in classrooms. Terminals were installed in regular classrooms. Teachers made highly variable use of the PLATO lessons. The evaluation was "soft" in the sense that it relied heavily on classroom observations, narrative reports of ongoing process, and understandable unwillingness on the part of the researchers to attempt to generalize findings across classrooms. Nonetheless, achievement and attitude outcomes in the two subject areas were measured.

Treatment effects were assessed using appropriate standardized tests (CTBS) and a set of specially constructed curriculum-referenced tests. In mathematics, significant average treatment effects were found at all grade levels (four, five, and six) for various curriculum specific tests and subtests of the standardized measures. These findings represented interactions of grade and treatment, and were consistent with the differences in the instructional strands. Significant school-by-treatment interactions were also obtained for these measures. The interactions, illuminated by observation and interview data, appeared the natural result of variations in teacher use of the materials. Treatment effects were greatest for topics emphasized by both the PLATO lessons and the teacher; even where teachers elected lesser topic coverage, treatment effects were still positive. With respect to reading, a well-controlled pilot study of the PLATO reading curriculum in the first grade yielded significant negative results. These early findings led the developers to rework the early reading materials during the demonstration year. A controlled study was conducted of the kindergarten classes, however, balancing morning and afternoon children. Interestingly, despite limited exposure to PLATO of less than five minutes a day during the term over which the evaluation was conducted, group achievement was affected significantly and negatively. Four classes, two morning and two afternoon, yielded a total of 68 PLATO and 67 non-PLATO children. In three of the classes, there were significant negative achievement scores on standardized tests for the PLATO group compared with the non-PLATO group. A small, positive effect was observed in one class. On the curriculum specific tests, positive and negative findings balanced each other out. Attitude results for both subject areas revealed grade and subject area differences, generally but not significantly more positive than negative, and higher for mathematics than for reading. The evaluators pronounced the elementary mathematics curriculum (in its "add-on" mode) a success, particulary when integrated with the teacher's coverage of mathematics. Overall, the evaluators were enthusiastic about the potential of the medium for providing attractive, flexible, and interactive instruction. Their conclusion that computer-based instruction is a treatment that interacts with its setting suggests that quality of the curriculum and use by teachers are major factors in the success of computer-assisted instruction.

The Los Angeles CAI Evaluation

The Los Angeles CAI Program. A four-year longitudinal study was conducted by ETS of the uses of CAI for compensatory education in elementary grades. The study was funded by the National Institute of Education and involved four Title I elementary schools in the Los Angeles (California) Unified School District. In each of the schools, computer labs were equipped with terminals and printers operated by a minicomputer, and half of the students, randomly assigned, visited the lab for between 10 and 20 minutes a day over the four-year period. CAI was provided by drill-and-practice curricula in mathematics for grades 1-6, and reading and language arts for grades 3-6. These materials were produced by the Computer Curriculum Corporation (CCC). The curricula were intended to reinforce skills that had been taught in the regular classroom. Students were tested each fall and spring with standardized tests (the Iowa-ITBS- and Comprehensive-CTBS-Tests of Basic Skills) and curriculum-specific tests.

Results. In mathematics, with exposure times averaging 10 minutes a day, CAI students showed significant positive effects in computational skills compared with control students. With 20 minutes of daily exposure, gains in computational skills were doubled. Longitudinal data revealed continued and increasing gains in computational skills with two and three years of CAI in mathematics. Positive effects were observed in mathematics concepts and applications in the first two years of CAI but failed to persist thereafter. In reading and the language arts, smaller but consistently positive results were obtained with 10 minutes of CAI daily over the period of one year. These skills were maintained but not increased with additional years of CAI. Attitudes were measured for the longitudinal sample, using a variant of the questionnaire developed earlier at ETS for the PLATO elementary demonstration. Attitudes toward reading, toward math, and toward school, and a measure of internal responsibility for success were included in the questionnaire. Attitudes toward reading and feelings of internal responsibility for success were significantly higher among students who received CAI than among students who did not, although CAI students' attitudes toward reading were more positive even before CAI was begun. A cost-benefit analysis conducted on the same data concluded that the cost of CAI in this study could be estimated at $130 for one 10-minute session throughout the school year and that the benefits in mathematics were about equivalent to the benefits that might accrue from equal amounts of tutoring.

The authors of the report concluded that they had demonstrated the utility of CAI in terms of improving test scores with students in need of compensatory education and with students who performed initially at grade level. There was greater and more continued success with mathematics than with reading and the language arts. In this respect these findings are consistent with the findings of other studies that focussed on mathematics in the elementary grades.

Review of the Literature

The difficulties with the studies on the educational uses of computers as a body of literature are manifold. First, the literature tends to be atheoretical and unsystematic, born primarily of the need to evaluate a particular computer course or approach in a particular context for use with a particular audience. The various studies are separate and independent, seldom building on one another or on what went before. No one study is a replication of any other study. Designs vary, grade levels vary, subject matter varies, student populations vary, classroom arrangements vary, outcome measures vary. Needless to say, the results are also variable. Frequently, the results appear to contradict one another. In all fairness, the vast majority of the studies are conducted within the very real constraints of operating classrooms and educational institutions. One positive note is that time (and perhaps the review process) have brought improvements in the design and conduct of such studies; later studies are more carefully planned and carried out than were earlier ones.

Recent attempts to make sense of the literature have inspired a variety of reviews and summaries. The reviews describe the major evaluations and give impressionistic accounts of their major findings (e.g., Kearsley, Hunter, & Seidel, 1983), or they attempt to quantify the findings across studies (Kulik, Kulik, & Cohen, 1980; Kulik, Bangert, & Williams, 1983).

Major reviews. Kearsley, Hunter, & Seidel (1983) present a sweeping report of "large-scale implementations of computer-based instruction and their corresponding evaluations". These include the PLATO and TICCIT studies already discussed here; the Computer Curriculum Corporation (CCC) programs, of which the Los Angeles CAI study is an evaluation of one of the 24 installations of that system; NDPCAL, a program in England intended mainly to promote sharing of courseware; and a handful of computer applications in non-traditional teaching environments. Among the latter are CARE, a computer-assisted program to diagnose educational handicaps using a mobile van; the CDC HOMEWORK project, in which the PLATO system was used to provide education and work opportunities to disabled veterans at home; the Lamplighter School, organized around the use of LOGO in classrooms; the use of PLATO in prisons; and, finally, the placement of computers in museums, libraries, and playgrounds, the latter exemplified by Sesame Place and ComputerTown, USA. These are included as examples of the ways in which the computer may challenge traditional approaches to learning. Kearsley and his colleagues conclude that the reports demonstrate that computer-based education on a large scale is both effective and practical under appropriate conditions.

Among the separate conclusions reached by Kearsley and his associates are that there is ample evidence that computers can be used to make instruction more effective and efficient and, in fact, exciting, satisfying, and rewarding for the learner. They are quick to caution, however, that the benefits are not inherent in CAI, but that positive outcomes depend on good teachers and good courseware. The authors assert also that not much is known about how to individualize instruction and

that, while computer-based instruction has demonstrated the potential of individualized instruction, the potential has not been achieved in sophisticated ways. (More will be said about this later, in a discussion of learner control.) Nor, they say, is much known about the major instructional variables involved in CAI.

Other reviews attempt systematic assessments of the results of different studies. These reviews report findings in two primary ways: the box-score and the meta-analysis. The former simply reports results across studies as a function of the ratio of positive to negative results, that is the ratio of results that favor computer-related instruction over the results that favor traditional instruction. Meta-analyses combine the results of studies in quantitative fashion.

Meta-analyses. The main metric of the meta-analysis (Glass, McGaw, & Smith, 1981) is the Effect Size (ES), a statistic that is computed as the difference between the outcome means of the experimental and comparison groups over the standard deviation of the comparison group. Because certain quantitative measures are required by meta-analysis, the criteria for inclusion of a study in such an analysis are more stringent than those that appear in box-score reviews, where only cursory efforts are made to screen studies for methodological flaws or rigor of analytical procedures.

Kulik, Kulik, & Cohen (1980) used meta-analytic techniques to examine the aggregated results of studies of computer-based college teaching. The initial bibliographic search turned up over 500 studies in the specified area, which number was reduced to 180 reports that were actually read by the authors. Of these, 59 met the criteria established by the authors for inclusion in the meta-analysis: The studies had to have been conducted in actual college classrooms and had to include quantitative measures of outcomes in both computer-based and conventional (control or comparison) classes. Flawed studies were eliminated. A study might be eliminated, for example, if treatment and control groups were clearly different in initial ability. Four types of computer-related instruction were represented by the 59 studies: tutoring, computer-managed teaching, simulation, and programming. The uses of computers in the studies included supplementary instruction and substitution for regular course elements. The time element also varied from a single unit of instruction covering a week or two to the full duration of a course. The studies were coded for 13 features that included the variations just described and others as well: features of the experimental design, the course setting, and the publication of results. Five outcomes were examined: student achievement, aptitude-achievement correlations, course completion, student attitudes, and instructional time.

Achievement measured by examination was reported in 54 of the 59 studies. Of these, 37 reported results favoring computer-based instruction and 17 reported results that favored conventional instruction. Fourteen of these differences were statistically significant, and the ratio of superiority of computer-based to conventional instruction was 13:1. The average effect size, .25 standard deviation, was judged small, although the individual effect sizes varied from study to study. Only

one study feature was systematically related to the size of the achievement effect, and that was the instructor. Assessment of the correlation between attitude and achievement revealed at best a small effect of computer-based instruction, and this in the negative direction. In 13 of the 59 studies, data concerning course completion rates were available. There were no real differences between computer-based and conventional classes in withdrawal rate (the obverse of course completion). These findings of no difference contrast with the findings from the TICCIT evaluation previously reported. In 11 of the 59 studies, data on attitudes toward instruction were obtained. Computer-based instruction classes exhibited more positive attitudes in eight of the studies, conventional classes were more positive in their attitudes in three. The eight studies in which instructional time was measured quantitatively all showed statistically significant differences favoring computer instruction. The averages were 3.5 hours of instructional time per week for conventional classes, 2.25 hours for computer-based instruction. This was judged the most dramatic finding of the meta-analysis.

A second meta-analysis by Kulik and his associates (Kulik, Bangert, & Williams, 1983) focuses on studies of mathematics instruction in grades 6 through 12. A bibliographic search yielded 51 studies that fit the first three requirements; three of these were eliminated because of methodological flaws. The remainder were categorized according to the type of computer application involved (e.g. drill-and-practice, tutoring); whether the computer was used to supplement or supplant conventional teaching; the duration of the study; and a series of additional variables reflecting such features as the assignment of students to control groups, and the use of a pretest. Six outcomes were identified, although again, not all studies included all outcomes. The six outcomes were achievement, retention (of subject matter content), attitudes toward subject, attitudes toward computers, attitudes toward instruction, and time to learn. For each outcome, using all relevant studies, the authors provided both box-scores and effect sizes. Only achievement was represented by all 48 studies. Kulik and his associates report a box-score of 39:9 in favor of computer-based instruction and an aggregated positive effect size of .32 standard deviation, a statistically significant effect. As with the college level meta-analysis, no strong relationship was found betweeen features of the studies (whether the computer was used to assist, supplement, or supplant the teacher, for example) and achievement. Two trends were apparent, however, in the borderline relationship between the year of publication of the studies and the existence of positive effects (recent is better), and between the duration of the study and the existence of positive achievement outcomes (shorter is better). Five studies included measures of retention of material after between two and six months. The box score (4:1) favored computer instruction, though the effect size of .17 standard deviation was not statistically significant. For the four studies that measured attitudes toward computers, the box score favored use of the computer (4:0) and the effect size was a statistically significant .61 standard deviation. Four studies also measured attitudes toward instruction. For these, the box score favored the computer but the effect size (.19 standard deviation) was not significant. Overall, the Kulik article reports results that are

consistent with those from other reviews of computer-based instruction in elementary schools: moderate achievement effects, savings in time to learn, positive effects for attitudes that ranged from the significant to the not significant, and small positive effects for retention. There were also suggestions (not quantifiable across studies) in the data that the effects were larger for disadvantaged than for average or above-average students.

The overall findings considered so far start to converge. In individual studies, and in meta-analyses, we observe achievement gains of moderate size for a range of computer applications in instructional settings: different levels, different subjects, different instructional arrangements (supplementary, substitute). Attitudes toward the computer and toward the course improve in minor proportions. Course completion rates, where measured, tend to be lower than or equal to the course completion rates for traditional instruction. Finally, there are substantial savings in time for computer-related instruction. There are clearly no major drawbacks to the instructional uses of computers. Computers have not fulfilled our worst expectations for them, and while they have not fulfilled our highest expectations, they appear to offer more positive than negative outcomes.

So far so good. How can we use these findings to answer the question of whether or not computer-based instruction is ready to move into the home. Not very well, it would appear. For the vast majority of the studies that exist, with few exceptions, are limited to average effects and to the use of computers in settings that are schools not homes. All of the studies that have been examined in primary and secondary analyses have focussed on relatively large numbers of students working in educational settings of one type or another. Homes are not schools, and what works in schools may not necessarily work in homes. To date, few studies of the effectiveness of computer-based instruction have examined the phenomenon in contexts other than institutional ones. Despite the potential of the computer for use in distance learning, the potential has not been realized in this country. Nor has it been studied systematically in the countries (most notably, the United Kingdom) in which it has been attempted. Another important issue in this discussion is that of the teacher or instructor. Few studies fail to note the importance of the instructor. In the TICCIT evaluation, for example, variations in the role of the instructor mediated the achievement effects in the English courses. On the basis of observations conducted during the PLATO elementary school evaluation, the teacher was judged to exercise a powerful (if idiosyncratic) effect on outcomes. In the Kulik, Kulik, & Cohen (1980) meta-analysis of computer effects in college-level instruction, the instructor is implicated in a more quantitative fashion. Studies that reported relatively large effect sizes were those in which different instructors taught the computer and traditional classes. Studies in which the same teachers taught both computer and control classes reported low effect sizes.

One additional area of interest was alluded to in an earlier context. A small and not very systematic set of studies addresses the complicated question of learner control over instruction. A brief review of these studies will be presented next.

Learner Control in Computer-Based Education

One of the advantages of the computer for instruction, at least in theory, is its potential for individualizing instruction at many levels simultaneously. Students can be "branched" to different sequences and levels of difficulty. Decisions about amount of practice, sequence and pacing can be left to the student, totally or in part. The question for developers of home-based instruction becomes, then, one of deciding which decisions are to be left to the student and which are to be controlled by the computer. What does research tell us about locus of control in computer-based instruction?

A review by Steinberg (1977) summarized the studies that examined learner control by intention or as the by-product of other concerns. One study of control in a college-level remedial mathematics course identified four different levels of control that ranged from total computer control on the one hand to total learner control on the other. The intermediate conditions allowed students control over the sequence of topics or control over the sequence of topics and amount of practice. The researchers discovered that students who were allowed total control of their instruction did not perform as well on a mathematics posttest as students whose instruction was totally under the control of the computer. Students who had done poorly on the pretest performed particularly poorly on the posttest after being allowed total control of the learning. Interestingly enough, learner control did not improve student attitudes either.

It will be recalled that the TICCIT evaluation reported low course completion rates for TICCIT learners, a finding that the researchers attributed to the transfer of control to the learner. The PLATO and TICCIT projects represented very different philosophies of learner control. A basic premise of PLATO was that course authors make the crucial educational decisions. With TICCIT, it was intended that students control the course flow. Students could control learning strategies, including examples, help, practice, and difficulty level. Although the data related to control were not the main focus of the studies, the evidence available suggests that learner control is not universally beneficial. In at least one TICCIT experiment, students achieved as well as students in conventional mathematics courses, but the students who did not do well using TICCIT appeared to have used inefficient learning strategies.

In some CAI applications, students are given control over a single instructional variable like difficulty level, amount of practice, or sequence of topics. In a study of students in grades four through six who were allowed to choose the difficulty level of their arithmetic drills, it was discovered that the students tended to choose problems that were too hard or too easy. In a college-level science course, students chose problems that were too hard. Students in studies where they were given control over amount of practice chose more or less than the optimal (recommended) amount. Studies that examined student control of sequencing indicated that students were not always the best judges of optimal sequencing. High performers appeared to do the best job of selecting effective sequences of instruction.

One of the hypothesized benefits of learner control is an improved attitude toward learning. This, in turn, is thought to enhance attention to the learning task and, thereby, to improve achievement. Experimental data suggest that attitudes are sometimes, but not always, improved by learner control. Moreover, enhanced attitudes don't always result in enhanced performance. Performance under learner control in the studies reviewed by Steinberg (1977) was the same as performance in control groups, or worse.

The results summarized above are at best suggestive. They come from small numbers of studies, few of which were designed specifically to test hypotheses about learner control. Occasionally, the results are contradictory. What they suggest, however, is that under some conditions, students could and did manage their own instruction. Some of the students who managed their own instruction achieved as much as students who weren't allowed the option of control. However, poor students, when given total control of their instruction, used inefficient strategies for learning and performed poorly as measured by achievement tests in the subject of the instruction. Specifically, they tended to manage time poorly and make inadequate use of review strategies, and failed to complete the course within the intended time limit. It appears from the results of these few studies that more able students were the better managers of their own instruction, and the least able students managed the worst. Student control improved attitudes some of the time. However, enhanced motivation was not a guarantee of superior (or even equivalent) performance.

While these findings are tentative at best, they pose interesting questions for developers of educational software for home use. How much control should be given the learner, and over which elements should such control be given? There is some evidence that learner control may be motivating, but there is also evidence to suggest that motivation does not always improve learning. There is also evidence of individual differences in the ability of learners to control their learning in such a way as to enhance it. How are such differences to be treated?

Learning from Television

The literature just reviewed on the instructional uses of computers tells us that people do learn from computers. How much they learn and how much they benefit from that learning depends in large measure on who they are and on the context in which the computer-based instruction takes place. As noted, the majority of the research to date has examined computer learning in the context of the school, where the instruction is usually part of a large curriculum. There is not now a way to predict how learning with computers will work at home. We can only infer or look for approprite analogs of the computer phenomenon.

One possible analog is television. Like the computer, television is a medium with enormous capacity to educate. Like the computer, television was not developed primarily for educational purposes, but found its way into the home for other reasons. Once there, the medium assumed tremendous importance in informing, amusing, shaping the preferences and

behavior and, yes, educating large segments of the population. The lessons of television may be useful in delineating the possibilities and problems of home education.

Two major reviews of studies of the effectiveness of instructional television were prepared in the '60s. Chu & Schramm (1967) reviewed the results of 207 separate studies. These yielded 421 possible comparisons with traditional instruction. Of these, instructional television proved superior (in terms of achievement) in 63; traditional instruction proved more effective in 50, and there was no significant difference in 308. Students at all grade levels learned from instructional television, although younger children appeared to achieve more than those in high school and college. The effectiveness of instructional television cut across a variety of subject areas. Dubin and Hedley (1969) surveyed existing studies of the effectiveness of instructional television at the college level. Their survey included 191 comparisons of which 102 favored television instruction and 89 traditional instruction, although most of the observed effects were small and did not attain statistical significance. Like the studies of computer-based instruction, the studies represented by these surveys varied widely in the numbers of students included, the ages of the students and, most important, in the rigor of their design. A critical analysis of 250 of these studies led Stidall (1963) to exclude all but 33 from consideration for reasons of inadequate controls and inappropriate statistical analyses. Only three of these "acceptable" studies showed statistically significant differences between instructional television and traditional instruction; all three favored television.

Comparisons of attitudes toward instructional television and traditional instruction were also presented in the reviews just cited. Overall, although there was some resistance from teachers, particulary in the elementary grades, to the use of instructional television, attitudes were generally favorable. More favorable attitudes prevailed among elementary school students than among high school and college students. The latter preferred small discussion classes to instructional television, but instructional television was more favorably received than large lecture sessions. Favorable attitudes were apparent in all subject areas. As we have seen with computer-based instruction, liking instructional television was not always correlated with improved achievement. Finally, there was some evidence of a halo effect--initially positive attitudes attributable to the novelty of the phenomenon--but no systematic evidence that attitudes necessarily improved or worsened with time.

As we have observed to be the case with studies of computer-based instruction, the vast majority of these studies were conducted in schools. In the late '60s, however, Children's Television Workshop mounted its initial attempt to move television instruction into the home with Sesame Street.

Sesame Street was an early attempt to exploit the possibilities of television for teaching at home. The goal of Children's Television

Workshop (CTW) was to produce a show for preschool children that would be both entertaining and educational. The show was first telecast in November 1969. A summative evaluation of the first year of Sesame Street was carried out by ETS. About 1,000 children in five areas of the United States were pretested and posttested with a battery of tests developed especially for the evaluation. Information was also obtained via questionnaires describing the children's home background, their parents' aspirations for them, and their television viewing habits. Children were observed as they viewed the show. A content analysis was performed on the show itself in order to determine the allotment of time to each of the goals of the program, and the use of particular production techniques to teach each goal. The evaluators attempted to assess both intended and unintended outcomes of the program. Children were included who watched the show at home and at school. The sample included middle-class and disadvantaged children, children from suburban and rural areas, 3-, 4-, and 5-year-olds, and children with English and Spanish language backgrounds. Many of the children were followed for two years.

Results of the evaluation indicated that, in the case of Sesame Street in its first year of broadcast, television could be and was indeed an effective medium for teaching important facts and skills to children between the ages of three and five. Among the skills that were learned by all of the groups studied in the evaluation, (middle-class and disadvantaged; rural, urban, and suburban) were recognizing and labeling letters and numbers; classifying, and sorting. Children who watched the most learned the most. Skills that received the most time and attention on the program were the skills that were best learned. There was also evidence of some transfer of learning in that some children learned to do things that were not directly taught on the program. Although children who watched with adults appeared to do better than children who watched unsupervised, learning did not depend on formal adult supervision. Children who watched at home showed gains at least as great as those who watched at school.

The major finding, of greater learning with longer watching, held true despite variations in age, sex, geographical location, SES, intelligence, and home- or school-viewing. Three-year-olds gained most, five-year-olds least. In fact, three-year-olds learned skills that had traditionally been taught at later ages. A small group of Spanish-speaking children made spectacularly large gains.

A second-year evaluation attempted to replicate the findings of the first year, assess the effects of a revised curriculum, and provide longitudinal data on children from the first-year sample. Effects of viewing were examined for 29 goal areas of the program. Some (19) showed strong positive effects of viewing, others showed moderate positive effects of viewing, and still others showed no effects of viewing. No negative effects were observed. A follow-up study of first-year viewers who had entered school revealed that children who had watched Sesame Street most frequently during its first year were ranked more highly by teachers than their lesser-viewing peers on scales assessing general readiness for school, verbal readiness, quantitative readiness, general

intelligence, attitude toward school, relationship with peers, and physical coordination. By comparing cohorts (children at pretest of the second year with comparable children at posttest of the second year), it was possible to assess the effects of a second year of viewing. The major finding here was that Sesame Street in its second year seemed to affect two major domains. First, in the cognitive domain, viewers of the second year performed better on more complex goals than one-year viewers. A second set of effects involved attitudes. Two-year viewers appeared to have more positive attitudes toward school and more positive attitudes toward the race of others than one-year viewers of the show.

The evaluators concluded that they had demonstrated the educational value of Sesame Street. Despite enormous international attention to the show and to the evaluation, and despite continuing controversy over the value of the learning that was demonstrated to have taken place through television viewing, no one has seriously challenged that original conclusion.

The same researchers at ETS conducted a summative evaluation of The Electric Company in its first year of broadcast. Two separate experiments were conducted, one involving viewing in school and the other viewing at home. In two locations, students in first through fourth grades watched the program in their classrooms. Pairs of classrooms at each grade level were matched. One member of the pair was randomly assigned to the experimental (watching one program daily for six months) condition. In two other locations, students watched the program at home. Again, pairs of classrooms were chosen at each of four grade levels and one of the pairs was randomly assigned to the experimental condition. In the home-viewing experiment, the treatment was to have the teacher encourage students to watch the show at home after school for a period of six months. The sites for the in-school viewing experiment were selected so that the show was only carried during the school day in that area. Viewing was therefore contingent upon being in an experimental classroom. In the at-home viewing sites, all teachers in the study agreed not to show the program in their classrooms. However, the control group students were technically free to watch the program after school (and they did, as it happened). The "target" audience for the show was defined as all first graders, children below the median on nationally normed reading tests in the second grade, and children in the lowest quartile in the third and fourth grades. Classrooms were chosen to contain a preponderance of target children. Measuring instruments included a reading test developed specially to assess behaviors that were addressed by the show (these included knowledge, skills, and attitudes toward reading); a nationally normed standardized test of reading; a questionnaire for parents; a questionnaire for teachers; a viewing record; and a classroom observation record.

According to the results, all first and target second grade groups appeared to have benefitted from the show over a wide range of goal areas. Non-target second graders also appeared to have benefitted from viewing, although the results for this group were generally not statistically

significant. Significant positive results were obtained for the target groups in the third and fourth grades in some goal areas. Non-target children in these grades benefitted almost as much as their target peers. No systematic effects were observed for attitudes toward school and reading, however. The cognitive benefits of viewing accrued to students with Spanish language background and Black students as well as White students. While there was a benefit to all children, boys appear to have gained more in the second and third grades and girls more in the first and fourth grades. Watching the show in color or black-and-white did not appear to alter the effects.

In the at-home viewing conditions, it happened that children in the experimental (encouraged to view) classes did not view The Electric Company to a significantly greater degree than did students who were not so encouraged. Not surprisingly, there were no significant effects in any grade when children in experimental and control conditions were compared. In general, the authors concluded, the analyses provided little evidence for a beneficial effect of viewing The Electric Company at home, but did demonstrate considerable beneficial effect of viewing at school.

Equity Issues in Home Instruction by Computer

We have demonstrated that computers can be useful adjuncts to learning and speculated briefly that they may become increasingly powerful in shaping our educational future. From the analogy of television we have suggested that home learning via computer will be much more than a promise, it will be a reality; although the results are likely to be unsystematic and variable across individuals. In the remainder of the paper we address what we see as a major problem of computer-based instruction in the home when such instruction is viewed in the context of contemporary American education. That problem stems from the fact that computers, unlike television, are not a universally available medium. Where the vast majority of families in the United States have at least one television set, the number of homes with computers is severely restricted.

Marketing data for 1983 reveal that owners of the seven best-selling home microcomputers are an affluent well-educated lot (Talmis, 1983). Well over half of them reported annual incomes of $35,000 or more. Forty-five percent of them had postgraduate degrees. Ninety-three percent of the primary users of the microcomputers in 1983 were males. About 12% of the total use of the microcomputers was educational, accounted for mainly by children between the ages of 6 and 12. Assuming that new purchasers resemble current owners, home computers available for education will reside primarily in the homes of the wealthy and the highly educated and will be used primarily by men.

A recent article in the New York Times (Monday, June 4, 1984) reports that sales of home computers are about 30% behind the projections of such sales made in January of this year. It had been predicted that a surge in the purchase of home computers would occur just about now. Instead, several companies (e.g., Timex and Texas Instruments) have essentially pulled out of the market. Others have suffered losses and substantially

lowered their sales estimates. Unfortunately, the setback has involved mainly smaller, less expensive computers--those costing $1,000 or less. More expensive personal computers have continued to sell well. While many of these are bought for their use in businesses, a number are also purchased for home use. The result, it would appear, may be even greater inequity in the availability of computers for instructional use in homes, concentrating them ever more in the homes of affluent individuals.

Although the marketing data don't say so, it is probably safe to assume that most of the owner/users will also be white. To the extent that recent trends continue, computer-based education in the home will elude those who are poor, non-white, and female. The spectre raised by these demographic realities is one of increasing an already sizable educational gap between middle-and upper-income individuals, on the one hand, and lower income groups on the other. In another context, Turnbull (1984) has called attention to the irony of this situation. The evidence from the Los Angeles CAI study (among others) suggests that computer-assisted instruction when made equally available to all children can work to reduce the achievement gap between children of affluent and disadvantaged families. Preliminary data from the IBM Writing to Read project (Murphy and Appel, 1984) also provides dramatic evidence that achievement differences associated with socio-economic status can be reduced greatly through the educational use of computers. Attempts to redress potential imbalances are being explored in a number of locales. In Houston, Texas, computers are being placed in community centers for the use of disadvantaged students and their parents. In other communities computers are being located in libraries. In the San Francisco bay area, a project conducted by the Educational Products Information Exchange Institute is exploring the issue of equity with funding from the San Francisco Foundation. In Princeton, New Jersey, computers in schools are being made available after normal school hours to students and their parents. How these efforts will fare in attracting individuals without computers at home remains to be seen.

The special case of females has been of increasing concern to researchers, educators, and feminists alike. Anecdotal evidence abounds concerning the extent to which computers and their associated activities are male domains. More recently, as data have supported and augmented the anecdotal evidence, researchers have turned to questions of why sex differences exist in response to and uses of computers. Data from a survey of directors of computer camps and workshops (Hess & Muira, 1984) reveal overall male-female ratios of 3:1 in participation in such activities. The ratio varies by educational level. Comparatively larger proportions of the participants in elementary grades are female (30% as opposed to 25% of the total later on); the proportions drop off in middle- and high-school. A survey by Wilder, Mackie, & Cooper (1984) of students in kindergarten through grade 12 revealed small but significant sex differences across the grades in the sex-typing of computers and somewhat larger differences in attitudes toward computers. Boys and girls alike saw computers as the domain of males, although girls viewed computers as less male-appropriate than did boys. Across all grades, boys like computers more than girls. A variety of observational studies report

more interest in computers on the part of boys than girls, and more use of computers outside of the classroom. Fetler (1984) reports that parents do not purchase computer games for girls as frequently as they do for boys. And in the Wilder, Mackie, & Cooper survey, conducted in an affluent community, boys reported having computers at home more frequently than did girls. The differences seem to differ by use and by context, among other variables. Computer centers and video arcades are heavily male dominated (Lockheed, Nielsen, & Stone, 1983). On the other hand, computers in classrooms and offices are used equally by boys and girls, men and women (Becker, 1984; Gutek & Bikson, 1984). It would appear that discretionary uses of computers are dominated by males; when computer use is dictated by a curricular or occupational need, use is more equitable. There is also evidence that males and females react differently to both the hardware and the software features of computers, and that there may be real differences in the ways in which the sexes are affected by technology (Mandinach & Corno, 1984; Wilder, Mackie, & Cooper, 1984). No wonder, then, that there are sex differences in computer literacy (Lockheed, Nielsen, & Stone, 1983) and in performance in programming (Fetler, 1984).

Conclusion

Several things can be said by way of summary. It appears that people can and do learn from computers. Individual studies and meta analyses have demonstrated that the computer can be effective in delivering instruction to students of all ages, in classes representing many subjects, both as a supplement to and a substitute for traditional classroom instruction. The studies that have demonstrated the instructional effectiveness of computers have taken place, it is true, in schools; and, for the most part, computer-based learning occurred in the presence of substantial teacher intervention and careful attention to the place of the computer-based instruction in a total curriculum. The computer literature does not tell us how well computers might function in effecting learning in the home. However, evidence from television research, from Sesame Street in particular, does indicate that children can learn from the medium effectively at home. And, if the projections describing expected sales of home computers and educational software materialize, more and more people will take advantage of the possibilities offered by computers for learning at home.

It is well-nigh impossible to predict all the effects of increasing home educational uses of computers. There are undoubtedly many potential outcomes, the bulk of which we expect will be positive; but many of which, as is the case with unintended outcomes, are not foreseeable. Perhaps the major issues that beg to be addressed are those of coordinating home instructional efforts with activities to be accomplished in school and dealing with the significant questions of equity, both social and gender. These issues impinge directly on the question of the role and reponsibility of the teacher in effecting educational reform and on the role that schools will play in a world in which some students learn at home much of what was once learned in the early years of schooling. In this regard, there are two final points that we would like to make before concluding. One has to do with teachers, the other with schools.

First, with respect to teachers, there are no census figures to substantiate it, but the estimate is plausible: more programs intended to change the educational process were rained down on elementary and secondary schools in the past twenty years than during the entire history of public schooling. The nature of the desired change varied with the interests--vested and intellectual--of the reformers, and this diversity of ends was exceeded only by the varied means chosen to bring them about. The blueprints differed from one another on some critical aspects of effecting change. One of these aspects, the part the teacher plays in implementing proposed innovations, is especially relevant to today's topic. We know from the evaluations of PLATO and TICCIT and the meta-analyses of hundreds of studies that teachers assumed prominent roles in the effectiveness (or lack thereof) of computer-based instruction. We have learned from the television studies as well that teachers were influential in many ways, from encouraging students to watch particular programs at home to providing follow up to televised instruction. It is therefore imperative that developers recognize the absence of the teacher as they take steps to move instruction into the home. Conceptions of the teacher's role in reshaping educational practices have ranged widely, from the view of teacher as obstacle to change, whose influence is best counteracted or neutralized, to one that solicits the active support of the teacher and, in fact, views teacher development as the predominant aim. In all cases, the role of the teacher must be confronted by anyone seeking to alter educational progress.

Given the teacher's centrality in the educational process, it is surprising that decisions about implementation strategies have often been made with scant knowledge about the pedagogical values and constructs held by teachers. The question of the compatability of a program's goals with those of the teacher's has seldom been raised. This curious lack of interest in the teacher's viewpoint, the "odd gap" often referred to in teacher research, is all the more remarkable if one considers the universal aim of many innovations, bent on no less than the improvement of all instruction efforts.

This problem, of course, is not unique to instructional technology or the efforts to move instruction into the home and we do not mean to suggest that technology developers are more guilty than others engaged in instructional reform; however, it seems especially appropriate to raise the concern at this time as we consider strategies to meet the challenge of effective implementation.

Now for a final comment on schools. Schools will have to cope with the effects of home-based computer learning at a number of different levels. Computers for home use are bought primarily by the affluent, whose children already enjoy advantaged positions with respect to school achievement. Computers are used voluntarily more by boys than girls. In a world in which computer literacy (however we define it) is an increasing need for all citizens, it will fall to the school to redress inequities created by the differential use of computers by different segments of the populations. How are schools to accomplish this feat?

Schools have always been conservative institutions. Traditional patterns die hard, and not without resistance on the part of administrators and teachers alike. The advent of an age in which students arrive at schools with vastly different accomplishments in an important area of functioning will require innovative arrangements in schools. Schools will have to position themselves to deal better with all types of students, including those who may know more than their teachers in certain areas. The innovative arrangements imply new ways of organizing within and perhaps across schools. They imply decisions of a policy nature about the allocation of resources across and within schools. They imply acquisition of equipment, hardware and software. They also imply thoughtful ways of grouping students so that those who don't have computers at home can be taught along with those who do, to the detriment of neither group. They imply new modes of teacher training, not just in the uses of computers but in instructional management as well. Finally, they imply increased involvement of computer-wise students (and perhaps parents as well) in the instruction of other students and even teachers. In short, the move to computer-based instruction at home will create new challenges for schools and teachers. The challenges will require that schools and teachers, more than ever before, be willing and able to accommodate ever-increasing variability among students.

In closing, let us return to the topic, is computer-based instruction ready to move into the home? It will move into the home, whether we are ready for it or not. Computers, like television before them, can exercise important influences on the learning and development of our children, undoubtedly in ways that we cannot now anticipate. At the same time, the computer raises new questions, opens new challenges and presents new problems, particularly to our educational system. As computers appear in more and more homes, and children are exposed to more and more of the educational software provided by their parents, what is to be the stance of the educational establishment? How can schools and the policy-makers who guide them best use the learning that will inevitably take place outside of the traditional classroom? How can policy groups influence commercial hardware and software manufacturers to maintain standards of quality and to produce materials that will benefit all students, within the demands of the competitive marketplace? What will schools do to compensate the students from disadvantaged families that cannot provide home computers and the software that teaches? What will be done about the females who do not choose to use the computers that their families may have bought? How will teachers, a group traditionally lagging behind the larger middle-class society in its comfort with the acceptance of computers, develop the skills and enthusiasm needed to take instructional advantage of the existence of computers in many or most of their students' homes? The real question, it seems, is not whether computer-based education is ready to move into the home. Rather, the more pertinent questions is, are we, the educational community, prepared to meet the challenge that home-based computers present.